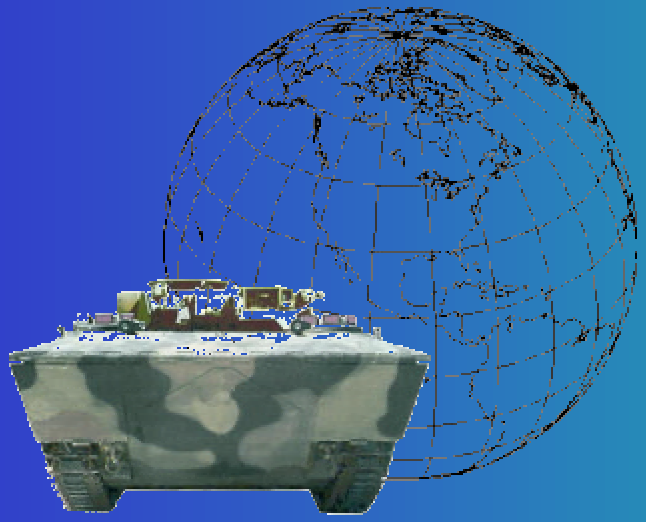
Replacing the *AAV-7*

George Akst, Center for Naval Analyses, 1994:

"Use of the *Amphibious Warfare Model* to Evaluate the Cost Effectiveness of Alternative Marine Corps **Amphibious Assault Vehicles**"



Arthur Aragon

George Brickhouse

Chad Henning

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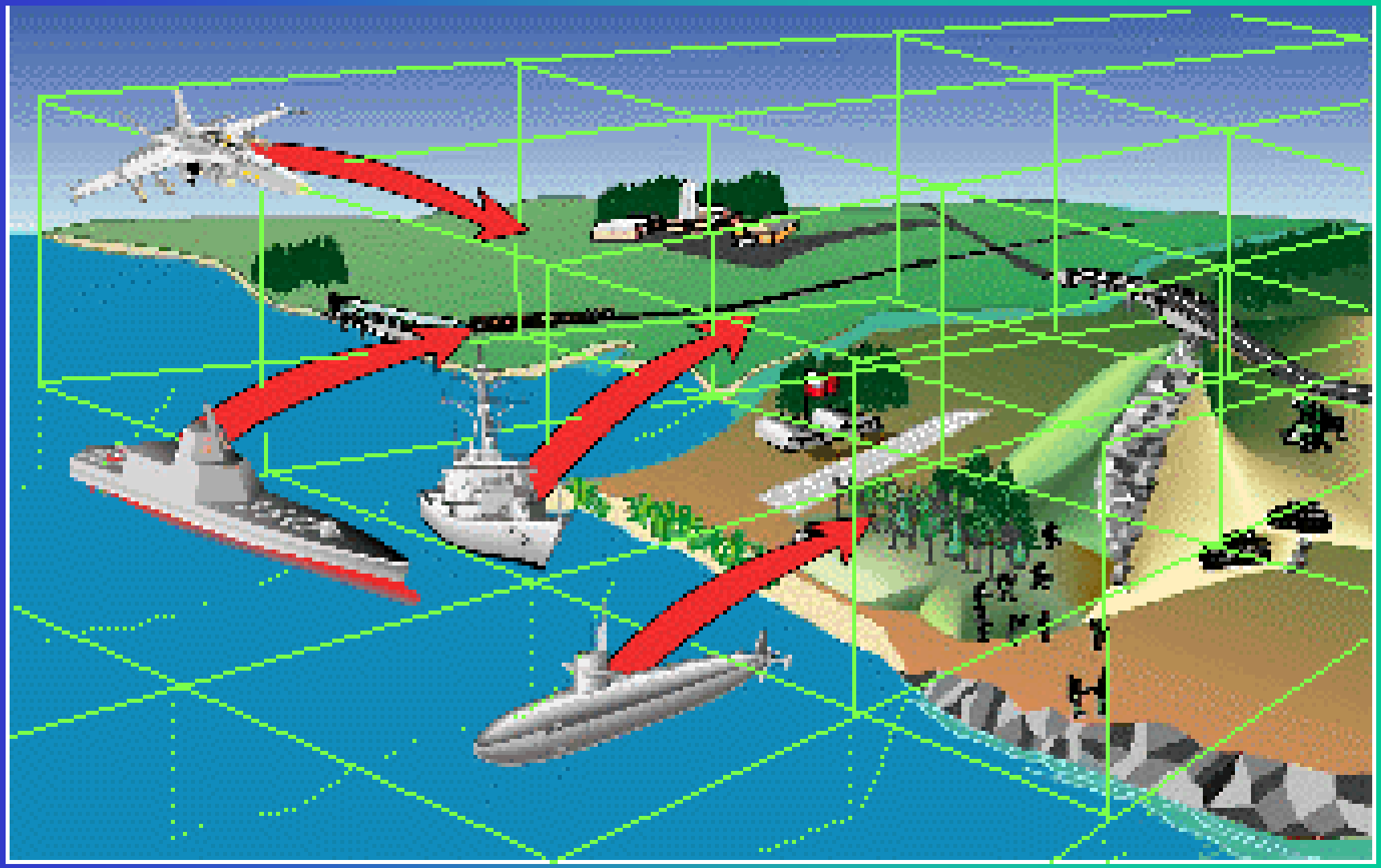
Amphibious Operations



…From the Sea

Replacing the *AAV-7*

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Outline

1. The AAV-7A1 & Replacement Alternatives

2. Evaluation
   - Performance & Cost Analysis
   - Ruling out some Alternatives

3. Amphibious Warfare Model
   - Overview, Flow of Events,
   - Attrition, Tactical Decision Rules,
   - Smoothing, MOE

4. Results & Conclusions

   Criticisms & Questions

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The AAV-7A1 and Replacement Alternatives

Introduction

- The Marine Corps' current amphibious assault vehicle has reached the end of its service life.
  - Designed in 1970's
- The article presents the methodology and results of a cost and operational effectiveness analysis,(COEA), conducted by Center for Naval Analysis, (CNA)

History

- Several programs to replace AAV-7A1
  - Mid 1970's: LVA program
    - Develop 20+ knot AAV
    - Program canceled in 1979
      - Too expensive
      - Too risky
  - Mid 1980's: Upgraded AAV-7A1
    - Slow swimming vehicle
    - Improved armor/firepower
    - Canceled due to high cost
  - Again in 1980's: OTH strategy
    - Led to LCAC
    - LCAC fell short, idea of AAAV conceived
    - Marine Corps asks CNA for COEA

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Plan

- Identify all alternatives
- Because of large number of alternatives
  - Conduct detailed evaluation of performance(cost/operational) on all the alternatives
  - Screen non-competitive alternatives
  - Model theater-level operations to determine relative contributions ….to overall force effectiveness

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Alternatives: Amphibious(fast/slow)

- AAV-7A1 PI
  - Upgrade of current
- AAV-7A2 (F)/(S)
  - Modernized version
- AAAV (F)/(S)
  - Super-duper version

The **AAV-7A1**

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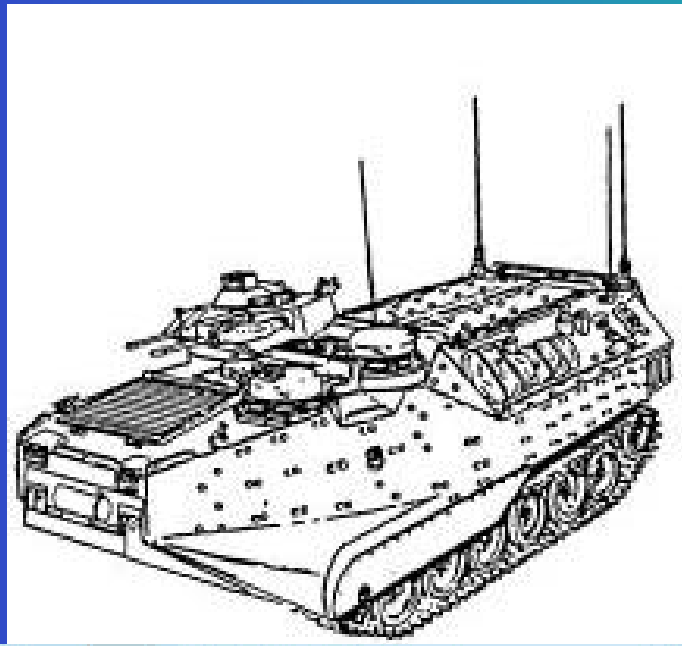

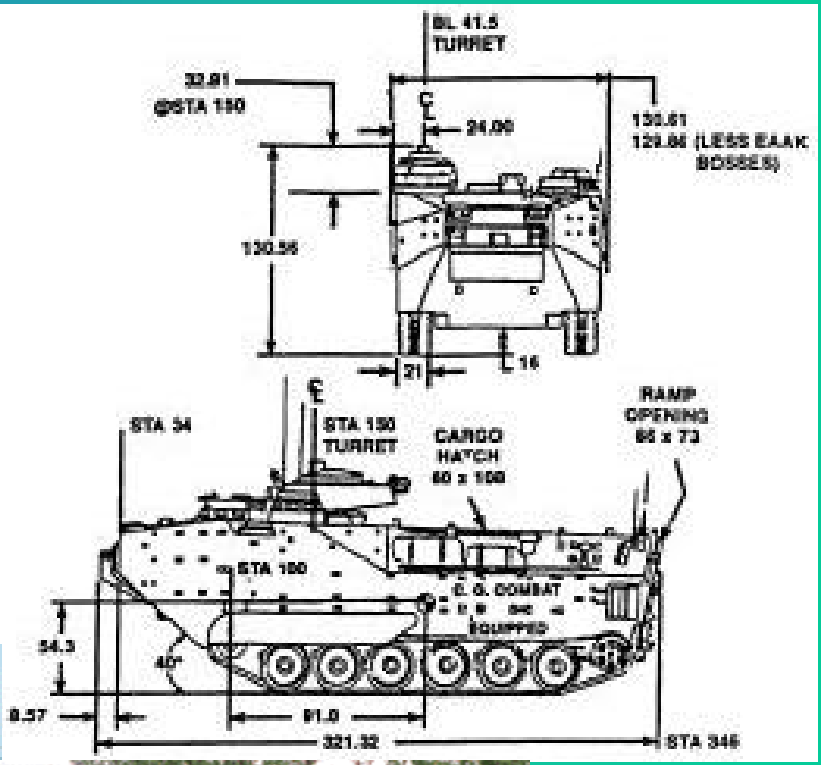

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The **AAV-7A1**

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Advanced AAV

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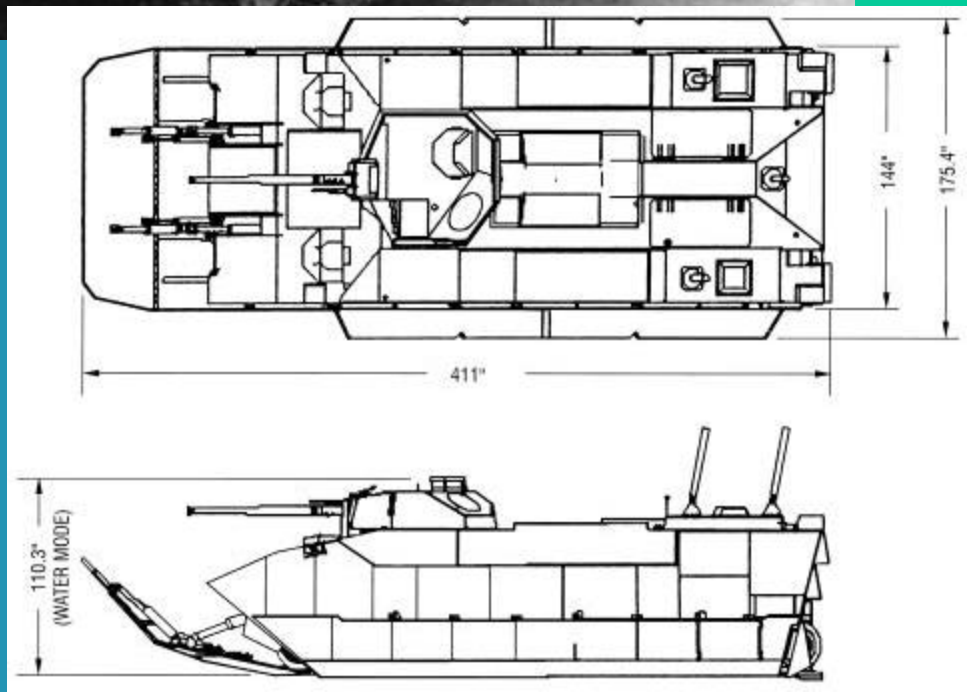
Advanced AAV



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More Alternatives: Non-swimmers

- LAV-25
- M113
- Bradley IFV
- FIFV
- APC(X)

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LAV-25

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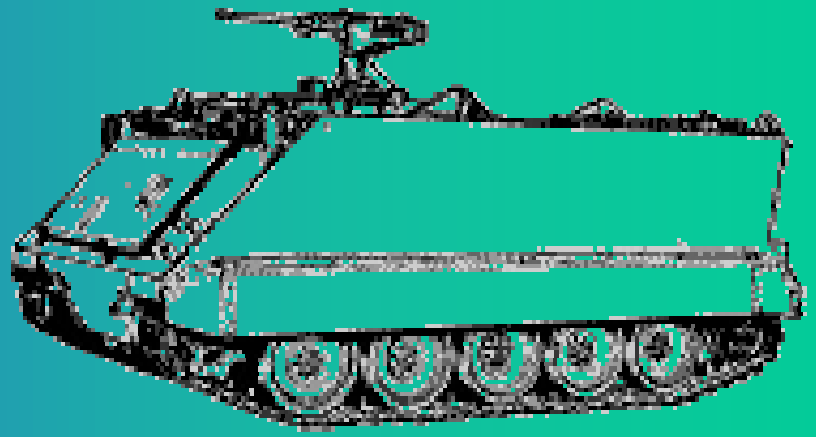
M113 APC



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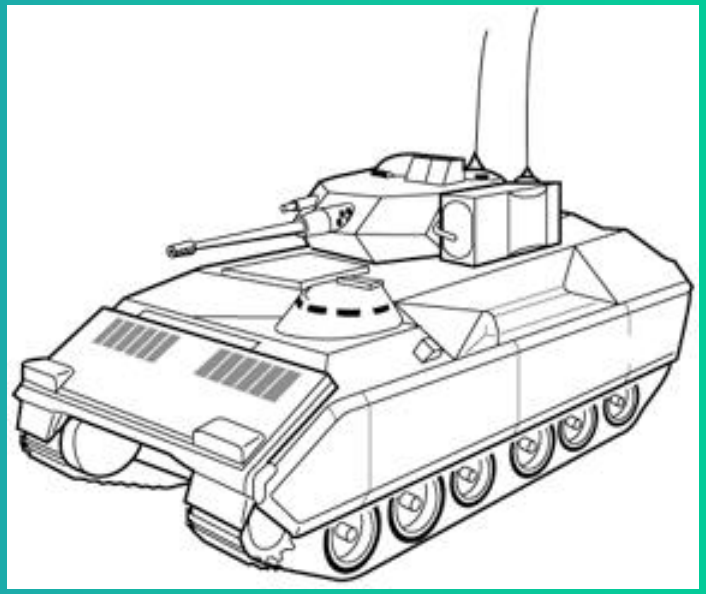
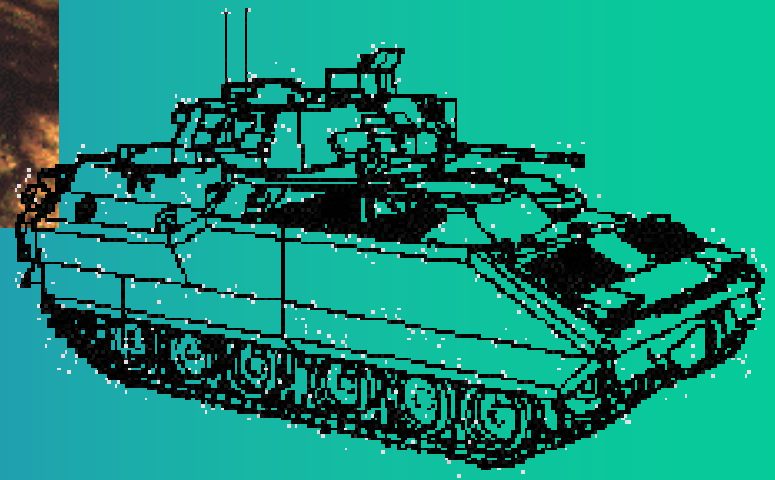
M2 Bradley





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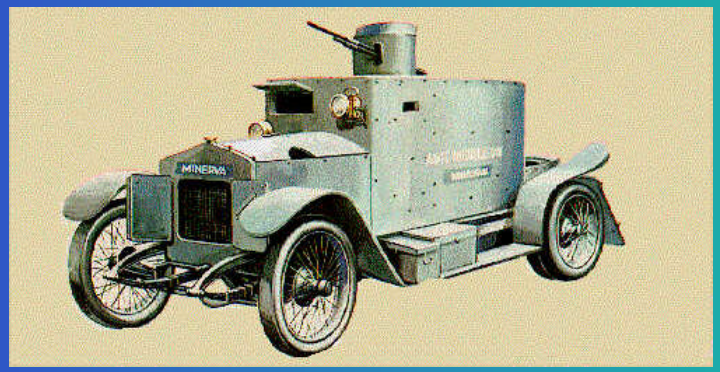
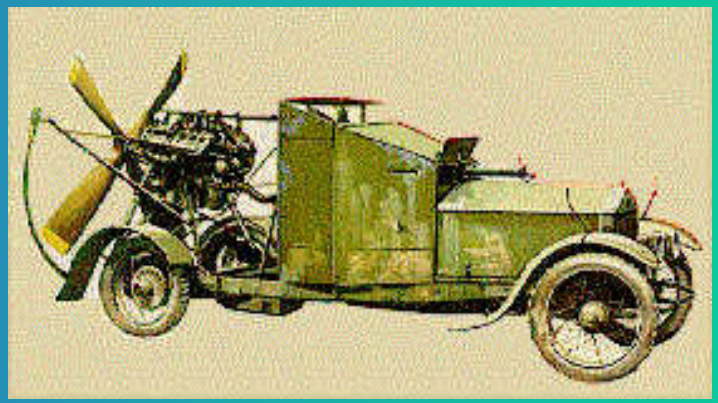
FIFV & APC(X)





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Alternatives: non-(land)vehicles

- Air option
  - CH46
- Surface option
  - LCAC with troop shelter

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Air Delivery

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LCAC Modifications

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LCAC

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Summary of **Alternatives**

Table 1. Characteristics of AAAV alternatives.

Alternative	Troops per vehicle	Vehicles per LCAC
Fast swimmers		
AAAV (F)	18	Not applicable
AAV7A2 (F)	9	Not applicable
Slow swimmers		
AAAV (S)	18	2
AAV7A2 (S)	18	2
AAV7A1-PI	18	2
Nonswimmers		
LAV-25	6	6
M113	9	4
Bradley	6	2
FIFV	9	1
APC (X)	18	2
Nonvehicle		
Air option[a]	12	Not applicable
Surface option	216	Not applicable

[a] CH-60 helicopters.

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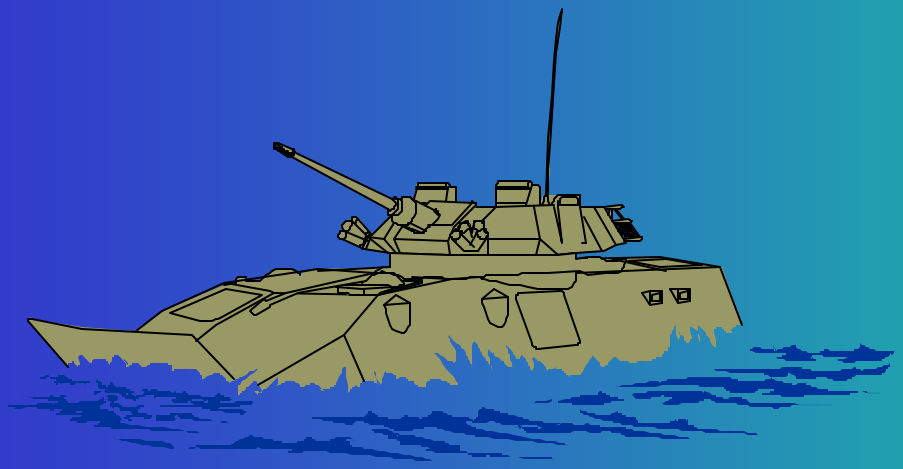
Evaluation

- Performance Analysis
- Cost Analysis
- Ruling out some alternatives



Performance Analysis

- Criteria
  - Ship-to shore movement
  - Mobility ashore
  - Survivability
  - Lethality

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Ship to Shore Movement

- Combat power build-up rate

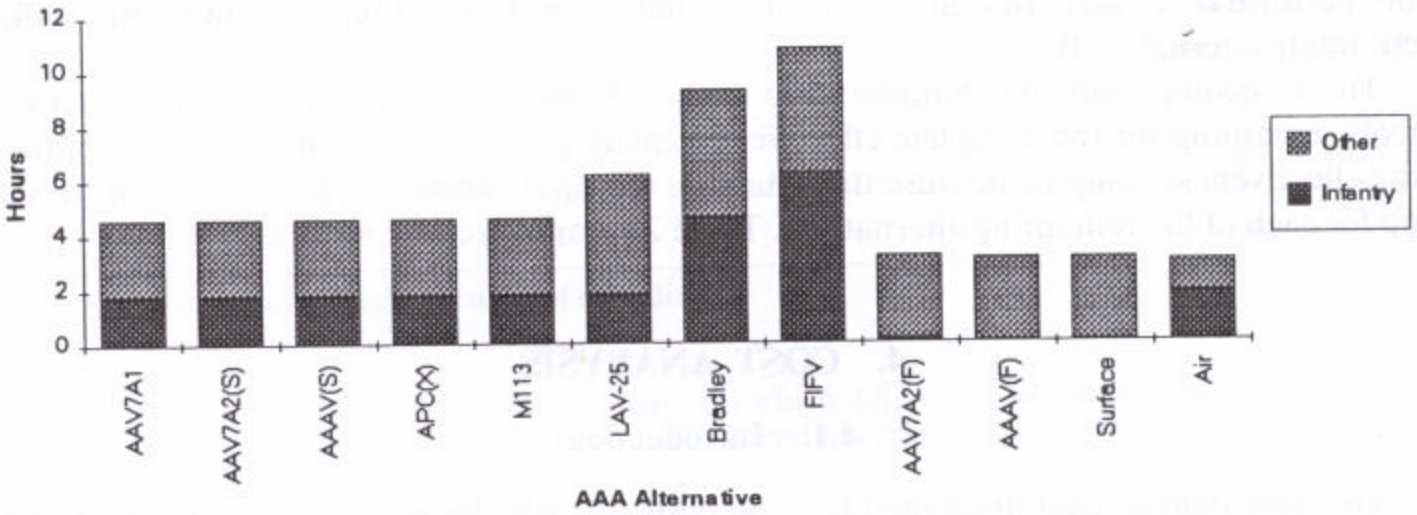

Figure 1. Time to deliver surface assault force.

Mobility

- Cancels out air/LCAC option
- Unclear criteria for mobility
- Highest: APC(X), AAAV(S)
- Lowest: M113, LAV-25
- Every other alternative in between

Survivability

- Probability of being hit
- Large targets
  - AAV-7A1
  - AAV-7A2
- Probability of being damaged
  - Most likely: LAV-25
  - Least likely: FIFV
  - What about LCAC?

Lethality

- Accuracy
- Armor penetration
- Requirement: "to be able to defeat enemy APC's and IFV's in 2005 era"
  - Highest: FIFV, but overkill
  - Lowest: M113
  - Every other alternative in between

Screening

- Dominance:
  - "if A outperforms B and is the same cost or less, then we can comfortably eliminate B"
  - Results of Performance Analysis

Table 2. Results of performance analysis.

Category	Alternatives retained	Alternatives screened out
Slow swimming	AAAV (S) AAV7A2 (S) AAV7A1	
Nonamphibious	APC (X) M113	LAV-25 Bradley FIFV
Fast swimming	AAAV (F)	AAV7A2 (F)
Nonvehicle	Surface	Air

Cost Analysis

- Life-cycle costs
- Discounted costs
  - "which we derived using a costing technique that considers time streams of expenditures"
  - AAAV(F) eliminates need for LCACs, this corresponds to a reduction in cost
- Based on equal-troop carrying capacity

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Cost Analysis

Table 3. Unit procurement and life-cycle costs for AAA alternatives (in millions of FY 1991 dollars).

Alternative	Average unit cost	Number of vehicles	RDT&E	Life-cycle cost		
				Procurement	O&S	Total
AAAV (F)	4.0	951	889	3791	2080	6760
AAAV (S)	3.0	951	631	2895	1863	5389
APC (X)	2.4	951	504	2256	1741	4500
AAV7A2 (S)	2.9	951	593	2729	1842	5164
AAV7A1	1.2	951	0	1181	1198	2379
M113	0.5	1769	0	952	1343	2295
Surface	—	—	0	3	0	3

Note: Numbers may not add because of rounding.

Cost Analysis Results

- AAAV(F) was most expensive
- “to consider the effects of differences in the streams of the costs involved, we also computed discounted costs. This did not change any of the relative rankings of the alternatives.”

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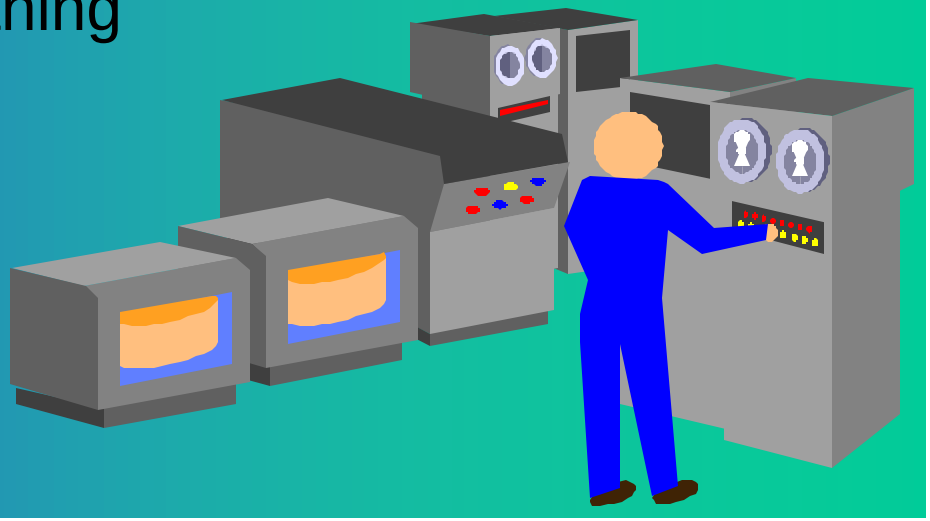
Amphibious Warfare Model

- Overview
- Flow of Events
- Attrition
- Tactical Decision Rules
- Smoothing
- MOE



Effectiveness Methodology

- Objective: Compare total effectiveness of Marine forces equipped with the alternative systems
- Chose 2 different scenarios to evaluate the force effectiveness

Effectiveness Methodology

- Low Scenario – employs a Marine Expeditionary Brigade (16,000 Marines) involved in a low- to mid-intensity conflict
- High Scenario – employs a Marine Expeditionary Force (50,000 Marines) involved in a mid- to high-intensity conflict
- Evaluated these scenarios using the Amphibious Warfare Model – All components of force taken into consideration

Scenarios

- Take place in the year 2010
- High Scenario takes into account mining of coastline
- Also, High Scenario takes carrier battle group support into consideration

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Model Overview

- Based on VECTOR-1 theater land ground and air campaign model with battalion level resolution
- AWM adds amphib aspects to the model to make a deterministic simulation of a conventional amphib operation
- Operates at a level of detail down to individual classes of weapons
- Has rather limited treatment of logistics and resupply

Model Overview

- Inputs – large set that describe weapons effects, order of battle, and terrain
- Model processes input data then proceeds according to predetermined tactical decision rules
- Advance force ops, cruise missiles, ship-to-shore movement, Assault landing, Air support

Model Overview

- Timeline – First 12 hours divided into 1 hour segments. Steps are 6 hours thereafter
- Battlefield Division – Divided up to 8 sectors and can be subdivided up to 30 sectors

Flow of Events

- Set of steps is divided into 2 major components: planning and execution cycles
- In each period each sector independently plans its portion of the battle
- Once sector planning is complete, it allocates aircraft across sectors based on a theater-wide perspective

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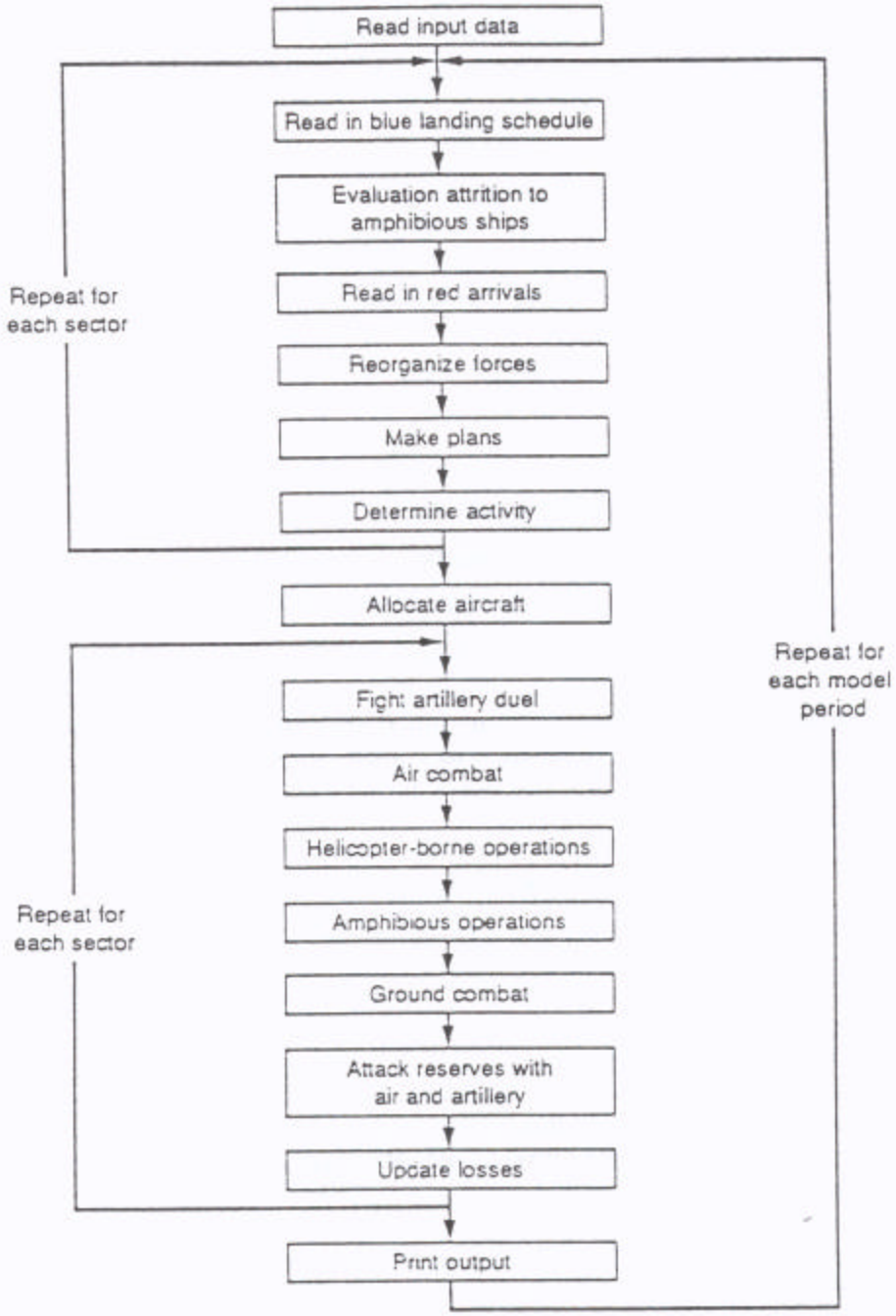

Figure 2. Flow chart for the amphibious warfare model.

Attrition in the Model

- In the direct fire engagement, both sides use aimed fire Lanchester equations
- For artillery duels both sides use area fire
- Air-to-Ground attacks are modeled using a geometric attrition equation

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Air-to-ground Geometric Attrition Equation

$$\Delta N = N * (1 - (1 - a)^n)$$

ΔN = target losses

N = the number of targets

a = the expected fraction casualties per sortie

n = the number of sorties

Mine Warfare

- Models mines using the following equation:
- Number of mines is also refined density is changed depending on how many are detonated

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Assault Vehicle/Landing Craft Attrition to Sea Mines

$$E(\Delta t) = N_m * (1 - M) * (1 - e^{-NW/C})$$

$$N_m = r * V * \Delta t * C$$

N_m = the number of mines in the area

C = the width of the mine field

M = the fraction of mines cleared by countermeasures

N = the number of craft transiting through minefield

W = aggregate mine damage width

r = sea - mine density

V = transiting velocity of craft

More Mine Equations

Number of mines detonated during a specific time period

$$E_x = \frac{E(\Delta t)}{P_k}$$

P_k = probability of kill per mine

Using equations above, mine density is modified by:

$$r' = r - \frac{E_x}{V * \Delta t * C}$$

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Tactical Decision **Rules**

- 21 rules in the model
- Aircraft Allocation: First allocate aircraft by mission and then further allocate mission-assigned aircraft to sectors
- Breakpoint Responses: Depends on force ratio and whether or not you are attacking or defending

Break Point Responses

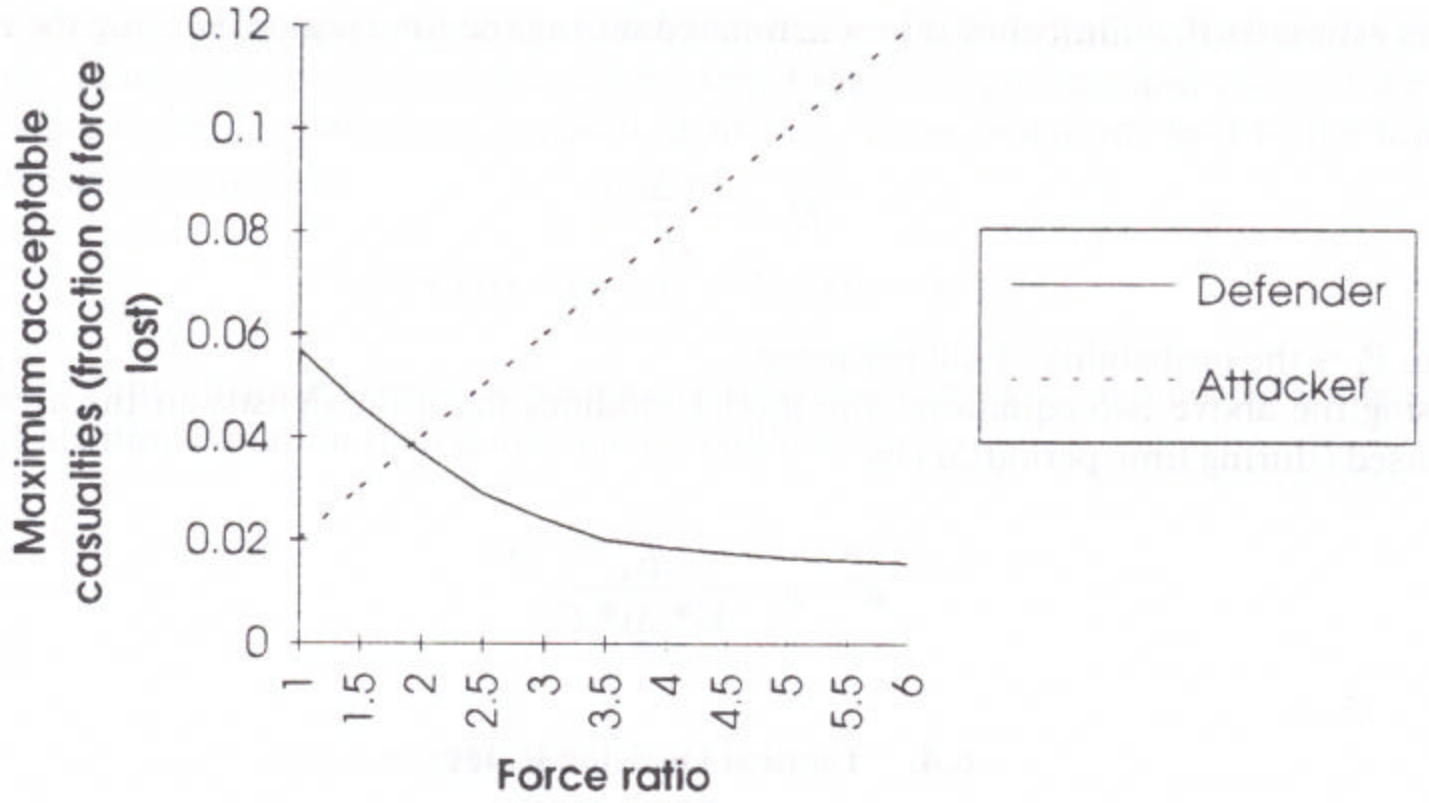

Figure 3. Maximum acceptable casualties as a function of force ratio.

Discontinuities

- Since time steps are fixed length, breakpoints can be exceeded
- To account for this, AWM uses a step back method that replays the last time step in smaller increments so that thresholds are not largely exceeded

Measures of Effectiveness (**MOE**)

- Force Buildup Rate
- LER
- Force Movement
- Force Ratio
- Losses by cause

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The Ending

- Results: MOE & Sensitivity Analysis
- Akst's Conclusions
- Our Criticism
- Questions

Results

- Run AWM for 2 scenarios and 7 alternatives

- AAAV(S), AAV7A2(S) & APC(X) the same!
  - Must compare them outside the model
- How well do the alternatives perform?
  - MOE Results
- Is the model too sensitive to input variables?
  - Sensitivity Analysis

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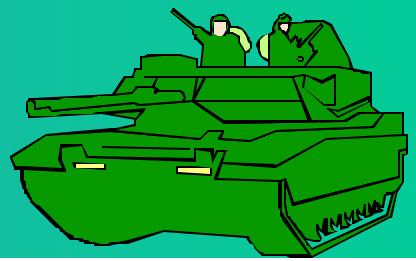
MOE Results: Force Buildup Rate

- AAAV(F) gets there quickest.

Table 4. Summary of ship-to-shore results.

	Low scenario			High scenario		
	Fraction arriving		85%	Fraction arriving		85%
Alternative	Hour 1	Hour 2	hour	Hour 1	Hour 2	hour
AAAV (F)	0.64	0.77	3	0.82	0.90	2
AAAV (S), APC (X), and AAV7A2 (S)	0.38	0.52	4	0.43	0.60	6
Surface	0.52	0.74	3	0.72	0.82	3
M113	0.38	0.52	4	0.45	0.63	5
AAV7A1	0.38	0.52	4	0.41	0.58	7



MOE Results: Loss Exchange Ratio

- Theater totals: level for all Marine forces
- Surface totals: some sectors depend on helicopters or landing craft.
- AAAV(F) scores highest.

Table 5. Loss exchange ratios.

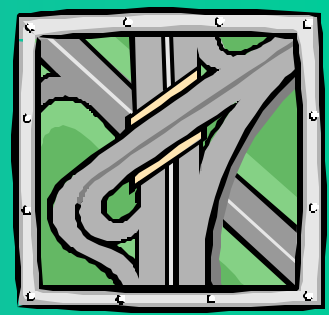
Alternative	Low scenario		High scenario	
	Theater totals	Surface totals	Theater totals	Surface totals
AAAV (F)	4.48	5.14	1.39	1.40
AAAV (S), APC (X), and AAV7A2 (S)	3.76	4.05	1.32	1.29
Surface	3.34	3.47	1.26	1.21
M113	2.98	3.01	1.24	1.14
AAV7A1	2.31	2.19	1.12	.99

MOE Results: Force Movement

- How far the force advances by end of battle
- AAAV(F) surpasses the others.

Table 6. Force movement (in kilometers).

Alternative	Low scenario		High scenario	
	Theater totals	Surface totals	Theater totals	Surface totals
AAAV (F)	101	111	24	36
AAAV (S), APC (X), and AAV7A2 (S)	88	90	22	33
Surface	77	71	15	19
M113	87	88	18	24
AAV7A1	83	82	22	32



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Sensitivity Analysis

- Sea-mine Vulnerability & the AAAV(F)
  - Tested a range of possible magnetic signatures
  - Negligible effect: loss of 2 at most
- Enemy Arrival Times
  - Low: over 4 days High: over 6 hours
  - Tested increased arrival rate (3 hours)
  - Hurt alternatives with slow ship-to-shore rate
- Equal Delivery (buildup rate)
  - # LCACs required is lowest for AAAV(F)
  - Could translate into reduced cost & improved mix

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Table 7. Summary results for arrival time excursion (High Scenario).

Alternative	Loss exchange ratio		Force movement (km)	
	Theater totals	Surface totals	Theater totals	Surface totals
AAAV (F)	1.33	1.45	23	36
AAAV (S), APC (X), and AAV7A2 (S)	1.15	1.10	21	32
Surface	1.15	1.13	14	18
M113	1.04	0.92	16	23
AAV7A1	0.85	0.68	18	27

- Using the AAAV will save money because fewer LCACs are required.

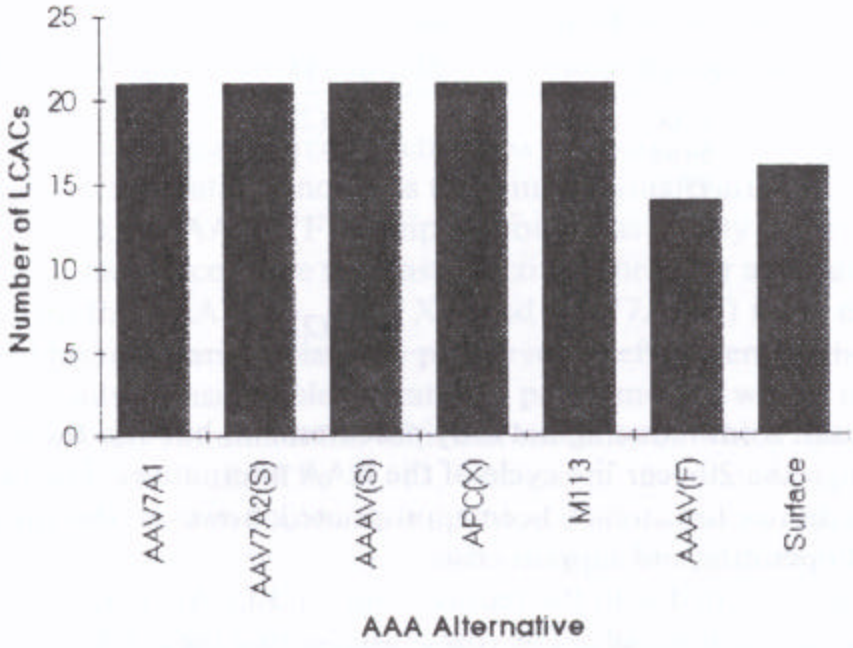

Figure 4. LCACs required for four round-trip deliveries.

Summary of **Results**

Table 9. Summary of results for equal-delivery case (High Scenario, surface sector only).

Alternative	Loss exchange ratio	Force movement (km)	First hour with 85% arrived
AAAV (F) (base case)	1.40	36	2
AAAV (F) (equal-delivery case)	1.32	34	3
AAAV (S), APC (X) and AAV7A2 (S)	1.29	33	6
Surface (base case)	1.21	19	3
Surface (equal-delivery case)	1.12	17	6
M113	1.14	24	5
AAV7A1	0.99	32	7

AAAV(F) wins! Surprise, surprise…

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Akst's Conclusions

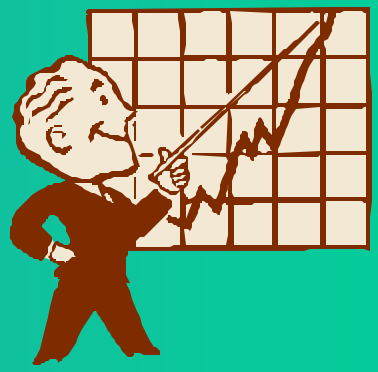
- Initial analysis ruled out 5
- Model and analysis produced Top 4: AAAV (F) & (S), AAV-7A2, & APC(X).

  Rule out the AAV-7, beaten by AAAV(S).
- AAAV(F) was best performer
- But also most expensive. Willing to pay?
- If not, AAAV(S) is better for close in.
- Lesson: The model played a key role in real-life acquisition decision-making.

Criticisms

- Was the result ever in doubt?
  - Marines got the answer they wanted. Even hinted at sources of funding (less need for LCAC).
- Some alternatives were not viable options.
- Paper lacked specific measures used in cost and performance analysis.
- Tactical Decision Rules not explained
  - “designed with the assistance of Marine Corps officers”

Review Questions



- What are 3 of the 5 MOEs used?
  - Answer: Force Buildup Rater, Loss Exchange Rate, Fore Movement, Force Ratio, Losses by Cause.
- How does Akst screen out non-competitive alternatives?
  - Answer: Using dominance in performance & cost analysis.
- T / F: The model used was divided into equal time steps.
  - Answer: False.

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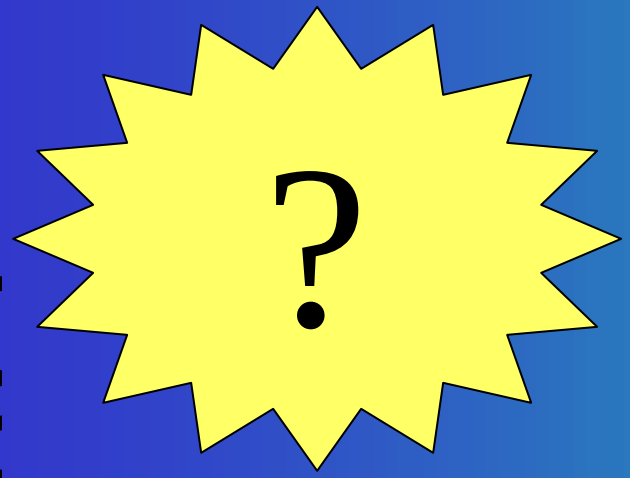

Questions?